2.3.4 Agriculture and Forestry

The Potential for Reduced Emissions

Sustained economic growth depends on having a secure supply of raw materials. Agriculture and forestry can supply additional and renewable resources for industrial production and energy needs. Currently, managed forest and agricultural lands in the United States fix 3.6 billion tonnes of carbon annually from the atmosphere. Most of this carbon is rereleased in short-lived products, and little is used to substitute for fossil-based products.

The primary opportunities to reduce GHG emissions in the agriculture and forestry sector lie in technologies that remove GHG from the atmosphere (carbon sequestration in durable biobased products, soils, and standing crops) and substitution of biomass-based products for fossil-based products. The carbon sequestration and renewable energy sections of this report cover carbon sequestration and biomass-based energy. The focus of this section is on development of biomass to bioproducts technologies (other than fuel) that can further reduce GHG emissions through both biomass substitution and reduced energy and fertilizer consumption.

Technology pathways that offer the best opportunities to realize these GHG emission reductions are conversion of biomass to bioproducts, advanced agricultural systems, and plant/crop engineering, as shown below.

Estimated carbon emissions reductions (MtC/year)

	2010	2020	2030
Total agriculture and forestry	3–7	15–25	30–45

Assumes successful technology development and subsequent marketplace adoption without significant policy changes.

Technology Pathways and Opportunities

Conversion of Biomass to Bioproducts. Annual crops, perennials, and short-rotation woody species represent plant/crop-based resources that are renewable source materials in the food, feed, and fiber industries (National Corn Growers Association 1997). The use of such biomass-based processes to produce materials and products provides a modest but significant reduction in GHGs because biomass-based feedstocks are synthesized from the CO_2 in the atmosphere and petroleum-based feedstocks are not.

Historically, plant/crop resources have seen limited use as industrial feedstocks in fossil material processing systems. However, in the future, biomass-based products are likely to become functional replacements for fossil-derived products with the same level of performance. The technology needs involve the following challenges:

- to use plant/crop-based inputs in modified processing systems
- to develop modified plant/crop production systems to provide desirable feedstocks
- to integrate these approaches to create optimized systems that generate a new economic platform based on the use of plant/crop-derived inputs

The use of plant/crop-based resources requires the development of concepts around “alternative processing” rather than just “alternative sources” for existing processes. New advances in biotechnology and plant genetics, new discoveries in organic synthesis using carbohydrates, and novel materials and micromanufacturing technologies should drive development of these new “alternative processing” options.

Substitution of biomass-based products for fossil-based products has significant potential to reduce U.S. GHG emissions. Additional emissions reductions could come from new markets, chemical production, process improvements, and energy savings. The forest products industry is 63% energy self-sufficient, and the cogeneration techniques it uses could be adapted to other bioindustries.

The barriers to use of biomass-based processes arise from the history of our country’s use of its indigenous resources. While biomass-based feedstocks are employed at competitive costs by the paper- and grain-processing industries, chemical manufacturing systems are optimized for petroleum and natural gas and are not designed to process alternative feedstocks. A successful scenario for using biomass-based processes involves the development of viable manufacturing platforms based on renewable forestry/crop feedstocks. These industries would produce materials and chemicals, such as cosmetics, textiles, and pharmaceuticals, that either would fill their own particular niche or would be integrated into the mainstream fossil-based chemical-processing industry.

Conversion of biomass to bioproducts is also discussed under Industry (Resource Recovery and Utilization) and Renewable Energy (Solar Advanced Photoconversion). Carbon reduction estimates are included only in Resource Recovery and Utilization.

Advanced Agricultural Systems. Agriculture and forest management practices have achieved significant increases in productivity and carbon fixation with decreased energy use. However, intensive agriculture and forestry production continue to add to the emissions of GHG and significantly affect nitrogen, soil carbon, and water biogeochemical cycles. Research should focus both on technologies that continue to increase productivity without increasing GHG emissions and on those which offer the possibility of significantly reducing GHG emissions. Advanced agricultural systems involve ways to deliver adequate quantities of nutrients that are efficiently assimilated by plants and water to maintain photosynthesis and support plant growth. Advanced agricultural systems include sensors, controls and monitoring, improved fertilizers and pesticides, improved delivery systems, genetic design of pest-resistant crops, and control of microbial processes. These technologies will result in increased biomass production for a given area of land with reduced nutrient, water, and energy inputs.

Advanced agricultural systems will lead to small but significant reductions in GHG emissions along with reduced energy consumption and fertilizer use. Currently, 3% of U.S. fossil fuel emissions result from agricultural crop production and only 27% of U.S. agriculture uses low- or no-till systems. Advanced agricultural systems technologies have the potential to significantly increase the use of no- or low-till systems. In addition, technologies that lead to improved fertilizer efficiency could result in significant carbon savings.

Some components of advanced agricultural systems, such as the use of global positioning systems to map yields, are in or close to commercial use. Others, such as real-time monitoring of water and nutrient status, are not. Although fertilizer delivery and chemistry have significantly improved during the last 10 years, advancements in biologically released fertilizers and control of microbial processes still require significant efforts. Detailed real-time and small-area geographic matching of fertilizers and other agricultural chemicals to plant requirements are in the early stages of development. Technologies involving biocontrol of pests are evolving; some are to the point of commercial development.

Plant/Crop Engineering. Plant/crop engineering is expected to contribute to reductions in GHG emissions through improvements in biomass production, carbon sequestration, and biomass conversion to bioproducts. Technologies include

- engineering plants with improved carbon-use efficiency, and therefore increased yield and carbon fixation
- control of physiological processes that determine a plant's ability to grow on low nitrogen and to recycle nitrogen
- manipulation of cell wall structure and assembly to create crops and to produce high-strength structural wood and composites for use in construction
- genetic transformation of desirable genes into target biomass plant species for specific biomass-to-bioproduct conversions

To successfully develop these technologies, basic research is necessary for better understanding of the metabolic pathways that control how plant productivity responds to changes in nutrients, water, and CO_2 concentrations. Research on gene insertion efficiency is also needed across the wide range of species relevant to bioproducts. In addition, gene identification to improve biomass quality is needed and will result from functional genomics research (sequencing and characterization of gene function).

Successful deployment of these technologies will occur only through integration with the development of bioproducts technologies and advanced agricultural technologies. Transgenic varieties and common crops are being introduced that are resistant to specific diseases and pests and that require smaller amounts of nutrients and water. They constitute a significant advancement in this field. Ecosystem assessments are needed as these new varieties are introduced. Because of the strong interdependency among advanced agricultural systems, the production of bioproducts, and plant/crop engineering, the carbon savings that can be realized with plant engineering are incorporated into the carbon savings reported in this section.

Strategy and Recommendations

Integrated research, both basic and applied, needs to be pursued in cooperation with commercial agricultural and forest sectors as well as with manufacturing industries. Key objectives should include integrated systems management and improvement of agriculture and forestry sustainability and cost-competitiveness.

Technical Risks and Other Issues

The rate of fundamental plant engineering research is limiting; it is inherently slow because of the life cycles of plants (especially trees). Ecological, commercial, and economic risks include the availability of and competition for land among agriculture, forestry, cities, and recreational areas. Trade-offs between food-feed-fiber and chemicals production have not been fully evaluated, and the environmental impacts of increased land cultivation will have to be carefully considered.